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Medium – to- Long Term Sustainability Threatened in the 4R Fishery for the Iceland Scallop

by

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Abstract

The 4R (Strait of Belle Isle) fishery for Iceland scallop has long been characterized by the absence of significant recruitment events. It is hypothesized that continuous, sometimes intense, fishing activity over relatively small areas may inflict collateral damage to recently settled scallops thereby impairing settlement of young and their subsequent recruitment. The fishery continues to be driven by a disproportionate dependence on residual pockets of low-to-moderate density contagions consisting primarily of old scallops. Scallop prices have remained sufficiently attractive to maintaining economic viability even with low catch rates throughout.

Based on a research vessel survey in 1997, fishable biomass was estimated between 7,570 and 11,035 t round ($\bar{x}$ = 9,302 t). Using a 10% exploitation rate, an appropriate catch level would be 930 t round. The availability in this fishery of critical volumes that allow catch rates to be economic is rapidly decreasing. A pulse fishing strategy, long the rule here, has now become less appropriate as the ability to opportunistically switch to other species in close proximity to home ports, has diminished considerably.

Résumé

La pêche du pétoncle d'Islande en 4R (détroit de Belle Isle) a longtemps été caractérisée par l'absence de poussées de recrutement appréciables. On formule l'hypothèse que la pêche continue, parfois intensive, pratiquée dans des zones relativement restreintes pouvait avoir des effets secondaires dommageables pour les pétoncles récemment déposés sur le fond et donc nuire à la fixation des jeunes et, ensuite, à leur recrutement. La pêche continue de dépendre de façon disproportionnée de poches résiduelles de concentrations, de densité faible à moyenne, de pétoncles généralement âgés. Le prix du pétoncle est demeuré suffisamment intéressant pour assurer la rentabilité de la pêche en dépit de la généralisation des faibles taux de capture.

Un relevé par navire de recherche effectué en 1997 indique une biomasse exploitable se situant entre 7 570 et 11 035 t de poids vif ($\bar{x}$ = 9 302 t). L'application d'un taux d'exploitation de 10 % correspondrait à des captures de 930 t (poids vif). La présence de volumes critiques autorisant des taux de capture rentables décroît rapidement. Une stratégie de pêche des poussées, qui a longtemps été la règle, s'avère maintenant moins appropriée car la possibilité d'opter, selon les besoins, pour la pêche d'autres espèces se trouvant à proximité du port d'attache est maintenant fortement réduite.

Introduction

Two species of scallops are found in commercial densities in Newfoundland: the sea scallop (or giant scallop), Placopecten magellanicus, and the Iceland scallop, Chlamys islandica. The sea scallop, the larger of the two, is restricted to the Northwest Atlantic. It ranges from shallow waters along the north shore of the Gulf of St. Lawrence to deeper water as far south as off Cape Hatteras. Its distribution is thought to be temperature limited. The species has long been exploited by both Canadian and U.S. fishermen. In Newfoundland, it is widely fished both recreationally and commercially, especially along the west and south coasts of Newfoundland. Offshore, the sea scallop is restricted to St. Pierre Bank (NAFO Div. 3Ps). A pulse fishery occurs here as and when significant recruitment is detected. The meats-only fishery is prosecuted intermittently by Maritimes'-based offshore vessels. An enterprise allocation (EA) program has been in place since 1989. Advice on the management of the offshore scallop fishery is through the Offshore Scallop Advisory Committee (OSAC). Conservation practices for the sea scallop on St. Pierre Bank include catch levels (currently at 50 t meats) and a size regulation which seeks to discourage growth overfishing by stipulating a minimum meat count (currently at 30/lb).

The Iceland scallop is more widely distributed than the sea scallop and is commonly found within the sub-arctic region of the north Atlantic. It is a sedentary, slow-growing and long-lived species. Commercialization is relatively recent. It is prosecuted by Canada, Denmark (Greenland), Faroes, Iceland and Norway. In Canada, fishing activity is restricted to Newfoundland and Labrador and Quebec. It is a seasonal, limited-entry fishery, some areas with specified catch levels (TACs). Management is through consultation with Regional Advisory Committees consisting of fishermen, processors, and the Department of Fisheries and Oceans.

First exploited along the Strait of Belle Isle (Gulf of St. Lawrence), the fishery for the Iceland scallop has now expanded into the Grand Banks of Newfoundland including St. Pierre Bank, and along coastal Labrador (Fig. 1). With an annual harvest estimated at 900 t round, the directed fishery for this species in the Strait of Belle Isle has persisted for some 30 years. At the present time, the fishery is regulated by a catch level and by season. Number of active licences varies widely peaking in 1985 at 107 vessels. Boats generally are in the 35-55 ft range.

Elsewhere, the directed effort commenced on St. Pierre Bank (NAFO Div. 3Ps) and eastern Grand Bank (NAFO Div. 3LNO) in 1989 and 1992, respectively. As well, coastal Labrador has become a significant producer. The high economic return from the scallop fishery tends to favour overexploitation. Fishing effort has expanded disproportionately in Newfoundland, primarily as a result of declining groundfish stocks and poses undue problems for medium-to-long-term sustainability of the resource. Approximately 50 vessels in the 45-65 ft. range participate in this offshore fishery sometimes extending beyond the 200 mi Canadian economic zone. The fishing fleet is highly mobile moving around continuously to improve or at least maintain catch rates. Once located, newly discovered aggregations are fished down rapidly, frequently within a single season, and sometimes pre-empt contemplated management or conservation measures. Declines in abundance are therefore not immediately apparent. Four separate areas over the eastern Grand Banks are now under TAC. Resource managers are now seeking to impose catch levels for four additional aggregations, two inshore and three offshore. Different gear types, continuous improvisation and modification of any given gear, ostensibly to improve catch rates over varying bottom types and fishing conditions and sometimes *ad hoc* changes to simply improve durability of fishing gear make comparisons using standardized effort and CPUE difficult throughout.

Resource surveys are conducted as and when necessary. Increasingly, acoustic ground discrimination techniques have been incorporated into surveys for these highly aggregated populations (Burns et al. 1995). Analysis of fishery performance and observer information are also factored into scallop assessments.

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Nominal catch of Iceland scallop in 1997 from Newfoundland is estimated at 11,136 t round, the highest in its 30-year history (Table 1). The recent proliferation of effort into this mollusc has put Newfoundland in the forefront as the world's largest producer of the mollusc, followed by Iceland (10,500 t), Denmark (1,689 t), and Norway (<300 t). Much of the removals in 1997 came from hitherto underexploited aggregations over St. Pierre Bank (NAFO Div. 3Ps) closer to ports than from beds recently commercialized offshore on the Grand Bank of Newfoundland. The Canadian portion of St. Pierre Bank accounted for some 48% of the nominal catch, followed by the Grand Bank (35%) and the Gulf of St. Lawrence (11%). Coastal Labrador (Nain and Williams Harbour) also made a significant contribution (6%) to total removals (Fig. 2).

Meanwhile, Canada and France had agreed to a 1997 TAC of 2,100 t round for Iceland scallops in the trans-boundary area within 3Ps. Consistent with the Canada-France Agreement (1994), the TAC was partitioned 70:30% in favour of France. Canada, with an allocation of 630 t, showed little interest in this area particularly after its huge success elsewhere on the Bank (Fig. 1). Only an estimated 7 t were taken. Together, the two countries harvested only 6% of the total allocation (125 out of 2,100 t). Based on the most recent (1996) scientific surveys, biomass within the trans-boundary box had declined to 13,000 t round from 18,400 t in 1993, a reduction of some 40%, this in spite of fishery removals estimated at only 300 t. Most significantly, the area continues to be plagued by starfish, widely considered to be significant predators of scallops.

Scallop prices were relatively stable throughout 1997 and, depending on count, ranged narrowly between $6.50-$8.00/lb meats. Overall, the fishery for the Iceland scallop in 1997 is estimated to have been worth over $20 million.

Gulf of St. Lawrence (Strait of Belle Isle, NAFO Div. 4R)

Scallop aggregations here occupy the Strait of Belle Isle along the northeastern Gulf of St. Lawrence. Fishing activity normally occurs from Ferrole Point northward to Cape Bauld and along the Labrador coast from Chateau Point to Red Bay. These nearshore, easily-accessed aggregations were first commerialized in 1969 (Naidu et al. 1982). Annual landings (Table 2, Fig. 3) are characterized by wide fluctuations, variously attributed in earlier years to a mix of price and availability of other species to the multi-purpose fleet. There are approximately 200 licensed scallop fishermen in NAFO Div. 4R. Of these 117 are located in Zone 14. In 1997, only 45 vessels prosecuted the fishery. Vessels typically are in the 35-55 ft. LOA range and make one-day excursions that result in a premium quality fresh product. The seasonal fishery is limited by quota, currently at 1,200 t round. A weekly vessel limit (800 lb meat or 7,400 lb round) is also in place. A dockside-monitoring program seeks to ensure compliance. Both shellstock and meats were landed during the earlier years. At present nearly all scallops are shucked at sea and only meats discharged at a number of ports along both sides of the Strait from Ferrole Point to Cook's Harbour on the Newfoundland side and from L'Anse-au-Clair to West St. Modeste on the Labrador coast. Overall the data base on fishery performance and stock abundance is somewhat fragmented. Science Branch (Newfoundland Region) has directed two research missions into this area since the return in 1994 of research mandate from the former Gulf Region. Prior to this, the last survey here had been conducted in 1987 by the Gulf Region (Lanteigne and Davidson 1987). We had invited fishermen to participate in both of our research missions in Div. 4R, but were unsuccessful each time.

At-sea sampling of catch and port sampling for individual meat-weight composition has been infrequent or non-existent. This assessment is based on an estimate of scallop biomass derived from a research vessel survey in 1997 and a detailed examination of fishery characteristics between 1995-97 in the context of historical performance (Naidu et al. 1996, 1997). For the first time resource management is seeking to establish a multi-year plan for this fishery.

Stock Status

From its inception the scallop fishery in the Strait of Belle Isle has been characterized by four strong peaks in landings: 1972-73, 1980-81, 1984-86 and 1992 to present (Fig. 3). In the past, each pulse was followed by several consecutive years of poor catches. Twenty-five percent of all removals (or 9,618 t out of 25,000 t round) from this 29-year fishery came in the six years immediately preceding the 1997 fishing season. The nominal catch in each of these years has exceeded the 29-year average of 860 t. In 1993 and 1994, annual removals were well over twice the annual mean.

An 11-day research mission was completed in the target area (2-12 September 1997). The survey was conducted after the 1997 fishing season. All fishing sets were completed with an 8 ft. New Bedford scallop rake equipped with 3" rings and interconnected with three and four links to the top and bottom respectively. Acoustic information on the distribution of bottom types between parallels 51°01'N and 51°55'N (Table 3, Fig. 4) first gathered in 1995 (Naidu et al. 1996) was improved slightly in 1997 (Table 4, Fig. 5). Dedicated ROXANN transects had been run in 1995. Spaced 5 mi apart, the transects had covered 225 linear miles over 847 sq mi of sea bottom. New information from the 1997 survey was incorporated into the ROXANN database for use in the 1997 survey.

Sets were assigned randomly over the whole area and abundance estimates adjusted to reflect distribution of available scallop habitat relative to bottom types encountered (Naidu et al. 1996). This allowed for a more efficient stratification of the area than would a simple stratified random survey based on some artificial stratifying variable such as depth. The survey design was such that the entire area was surveyed but abundance estimates were restricted to areas considered likely to attract commercial effort. Bottom type, as determined by ROXANN sweeps, is probably the best choice of variable to correlate with distribution and abundance of scallops. This approach is particularly appropriate for a highly aggregated sedentary species (contagions) such as the Iceland scallop. Not surprisingly, there is a considerable overlap between areas independently designated as "scallop bottom" and distribution of fishing effort in 1995-97. This overlap is clearly borne out in Figure 6 where research survey sets are juxtaposed over logged fishing co-ordinates. One hundred and forty-eight sets were completed over an area estimated at 611 sq mi (Table 5). Of this only approximately 285 sq mi (or 47%) was found to be suitable scallop bottom. The five scallop beds first delineated in 1995 (Naidu et al. 1996) were modified using new information (Table 4, Fig. 5). Bed 2, for example, expanded from 38 to 72 sq mi (+89%). Similarly, the size of Bed 4 was increased slightly (+2%) from 162 to 191 sq mi. Bed 5 was reduced by 55% (from 39 to 18 sq mi). A rather small previously unidentified aggregation (~1 sq mi, Bed 7) was also included in the 1997 survey. Catch rates were low throughout with the better catches coming from Bed 4 (Fig. 5). The best catch in the research survey at 19.3 kg or 43 lb/tow consisting of 110 scallops was also drawn from Bed 2 (which accounted for 1,104 t or 48%) of total removals from the area in 1997. Elsewhere catches were patchy, typically below 5 kg (or 11 lb/tow). Twenty-three sets (out of 148 or 16%) produced no scallops. Aggregations within Bed 1 and 3 appear to have been fished down. Consequently, they were added to the residual area (Area 6) considered unlikely to attract commercial effort. Minimum dredgeable biomass within areas likely to attract commercial effort was estimated at 1,514-2,207 (mean = 1,860 t round, Table 5). Using a gear efficiency of 20%, we estimate total biomass to be in the range of 7,570-11,035 (mean = 9,302 t round). Much of this biomass is contained within 191 sq mi or 68% of the total area considered favourable for the occurrence of scallop (Bed 4), followed by Bed 2, estimated 72 sq mi. Elsewhere, only a very small patch (Bed 7) produced encouraging catches. Tables 3 and 4 summarize and compare essential parameters between the 1995 and 1997 surveys.

Size Composition and Meat Yield

Overall, scallop sizes in the target area (Fig. 7) remain relatively large with a mean shell height estimated at 87.3 ± 8.9 mm, unchanged from the sizes encountered in 1995 (86.8 ± 8.6 mm) (Table 6). Overall meat yield (% of round weight) at 12.8% was higher than in 1995 (10.3%). With individual meat weights significantly higher in 1997, meat counts have drifted lower (32 versus 43/500 g or 39 versus 29/lb, Table 7). Again, conspicuous by their absence, is the continued scarcity of pre-recruit scallops, an observation first flagged three years ago (Naidu et al. 1996).

1997 Fishery

To facilitate compliance and enforcement, the Div. 4R fishing zone had been simplified in 1996 to include all areas north of Ferrole Point.

Distribution of Fishing Effort

Effort has continued to shift towards the southwest (Fig. 6) into beds thought to be long left idle. Removals south of 51°25'N have continued to increase in each of the last three years (Table 8). Based on log returns it is estimated that up to 83% of the nominal catch in 1997 came from south of 51°25'N or nearly twice the amount taken in 1994.

CPUEs

The overall non-standardized CPUE estimate based on lb (round)/tow has remained largely unchanged from the previous year (75 versus 71 lb/tow, Table 9). As in previous years, the fishing fleet appears to have moved around continuously to locate and fish beds with better catch rates. Highest CPUEs were again realized at the height of summer (June-July) when weather conditions typically are more favourable and daylight longer (Table 10). Three quarters of the nominal catch occurred in the June to July period during which an estimated 70% of the 1997 effort was expended. Overall, significant declines in catch rates were not evident until the fall when inclement weather probably impinged negatively on the quality of expended effort. Next to the largest component in the fleet (one vessel only in the 55-64 ft LOA size class), vessels under 35 ft LOA continue to report better catch rates than those in the two size categories in between (Table 11). The bulk of logged removals (37%) came from vessels in the 35-44 ft range.

Commercial Size Composition

Except for a one-time only sampling of the landed catch in 1997, we have no data on seasonal changes in size composition or of individual meat-weight frequencies. Based on a single sample consisting of 236 scallops (procured on August 5, 1997) mean shell size of scallops taken from 51°20'N and 57° 10'W (Fig. 6) is estimated at 84.8 ± 8.1 mm. Composite mean from the 1997 research vessel survey was estimated at 87.3 ± 8.9 mm (Table 6), and nearly identical to the size estimated in 1995 (86.8 ± 8.6 mm). Biologically dissected mean adductor muscle weight was estimated at 14.4 g equivalent to a 32 count/lb. Composite count from 10 such samples taken during the research vessel survey was 34/lb.

Natural Mortality

Natural mortality computed directly from percent occurrence of cluckers (persistent paired valves still attached at the hinge lines) was estimated (Dickie 1955, Mercer 1974) to be 0.16, similar to that estimated in 1995 (0.18) (Table 12). These are higher than the intrinsic value reported for the species (Naidu 1988), and, no doubt, include non-yield fishing mortality. More importantly, they are nowhere near the levels reported for other commercialized aggregations where natural mortalities have approached 0.9 (Naidu et al. 1996, Naidu and Briand, unpub. Data).

Starfish

Of the five species of asteroids found in the Strait of Belle Isle, Leptasterias polaris and Crossaster papposus, two of the most important predatory species, were also the most common, followed by Solaster sp. and Asterias sp. Their abundance, size composition (Fig. 8) and individual weights relative to other areas where significant scallop fisheries occur are summarized in Tables 13 and 14. Overall, starfish from the Canyons (LCC) had the highest individual mean weights followed by 3Ps. Size-wise (arm-radii) predatory starfish from the Canyons were again the largest. Leptasterias sp. from 4R were among the smallest anywhere. With the exception of Asterias sp., individual weights of starfish in 4R were among the lowest of all areas examined (Table 14).

Discussion

The 4R fishery for scallop is characterized by a disproportionate dependence on residual pockets of low-to-moderate density contagions consisting primarily of old scallops. There has been little recruitment into this fishery. In 1995, we had also cautioned that continued removals of the order of magnitude seen between 1993 and 1995 would likely result in the stock depletion that would render fishing uneconomic. As elsewhere, the fishery is driven not by total biomass available within the megapopulation, but rather by the availability of critical volumes that allow catch rates to be economic. The pulse fishing strategy, long the rule in this fishery, has become less appropriate as the ability to opportunistically switch to other species in close proximity to home ports, has diminished considerably. Northern shrimp may be an exception.

Consequently, the recommended catch level had been successively reduced in the last three years from 2,000 t in 1994 to "no more than 1200 t" in 1997. When asked for their view on catch levels for 1997, stakeholders for that fishery went with 1200 t, the maximum recommended. They agreed that the stock was declining but at the same time recognized that there are no alternative species for them.

Fishermen have also continued to challenge science assertion that there has been little recruitment into the stock. Fuelled by a false optimism, they have continued to allege that most of the small scallops pass through our research gear. That this is unlikely to be the case is demonstrated in Figure 9 which clearly shows that, where present, pre-recruits are indeed caught and retained in sufficient numbers to flag any incoming recruitment. The large areal shifts in 1996 and 1997, coupled with a plummeting research vessel catch rate in 1997 and the continued absence of pre-recruits throughout the target area suggest that the fishery can no longer sustain the level of effort/removals seen in recent years. Any real decline that reflects diminished availability over the total area has been suppressed by fleet behaviour whereby vessels continue to locate and fish down "hot spots". Also, scallop prices have been sufficiently attractive to maintaining economic viability even with low catch rates.

The recommended TAC at 10% of mean biomass would be 930 t round. We hasten to add that even this level of harvest is now considered high for the species. Both Sundet (Norway) and Engelstoft (Greenland) have recently supported our contention that exploitation rates for this very slow growing species, if anything, should be lower. Eiriksson (Iceland) continues to prescribe a harvesting level based on approximately 10% of estimated biomass. He writes "We are still working on harvesting levels based

on approximately 10% of estimated biomass. Seems to be working for this major area with good average recruitment, but definitely quite high for peripheral areas".

We continue to be concerned at the lack of significant numbers of pre-recruits in the northeastern Gulf of St. Lawrence. Three years ago in 1995, we had hypothesized that fishing activity itself may inflict collateral damage to recently-settled scallops with extremely brittle shells. Consequently, there is net loss of "productive capacity" in the area. This is exacerbated by the overlap in the narrow time window during which fishing activity must necessarily take place and the critical early life history stages of recently-metamorphosed larvae. Assuming that a typical tow covers a distance of 0.5 to 1.0 mile, and using an average gear width of 10 ft, we estimate that in 1996 the fleet completed between 18,000 to 36,000 linear miles corresponding to an area of perturbation estimated at 30-60 sq mi (Naidu et al. 1997). Corresponding figures for 1997 were 16,000-31,000 miles and 25-50 sq mi (Table 15). Even allowing for overlap of tows this is not inconsiderable and must affect recruitment dynamics in the area. About the only way to reduce or eliminate this large-scale perturbation to rehabilitate the stock would be to close off some fishing areas for extended periods and to examine patterns of recruitment within.

In spite of the presence in the area of predatory starfish species, we do not see dramatic increases in estimated natural mortality between 1995 and 1997. Unlike the early (1989-92) fishery on St. Pierre Bank, where shellstocking was the rule, nearly all scallops from 4R were shucked at sea. A full 85% of the nominal catch in 1997 was shucked at sea. Shells and viscera are thrown overboard usually close to the scallop beds. Consequently, starfish have abundant food to scavenge. Presumably, there is no energetic advantage to preying on live animals.

Managers should consult with stake holders with a view to establishing "refugias" where fishing would be disallowed for extended periods, say, of up to five years. Inaction in this regard will probably result in severe resource depletion throughout the whole area in a relatively short period. It may also be prudent to reduce starfish numbers by returning them for disposal at a land fill site or for composting.

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Table 1. Nominal catches (t, round) of sea scallops (offshore 3Ps only) and Iceland scallops from Newfoundland, 1969-97.

Year	4R	3Ps Iceland scallops (all SPB)		Sea scallops	Div. 3LNO		
					3L	3N	3O
1969	248						
1970	192						
1971	167						
1972	2,596						
1973	2,189						
1974	244						
1975	-						
1976	-						
1977	-						
1978	-			191			
1979	450			8			
1980	1,133			291			
1981	1,530			-			
1982	349			5,951			
1983	371			4,930			
1984	1,523			3,428			
1985	2,546			440			
1986	1,942			1,270			
1987	1,141			448			
1988	447			8,176			
1989	155	36		2,756			
1990	88	507		1,270			
1991	457	755		1,112			
1992	1,296	5,967		556	20	2	0
		Core	Non-core				
1993	2,122	-	667	1,079	489	325	3
1994	2,294	-	440	407	86	3,844	11
1995	1,497	230	31	564	101	6,400	0
1996	1,204	224	82	-	406	9,048	0
1997	1,205	125	5,245	-	292	3,188	0

Table 2. Iceland scallop landings and effort statistics[1] from the northern Gulf of St. Lawrence/Strait of Belle Isle. A species-specific conversion factor of 9.2 is used throughout.

Year	Landings (t, round)	No. of active licences	Effort (boat days)	Catch per unit effort (unadjusted)	
				kg (round) /boat/day	t (round) /boat/year
1969	248	-	-	-	-
1970	192	-	-	-	-
1971	167	-	-	-	-
1972	2596	-	-	-	-
1973	2189	-	-	-	-
1974	244	24	269	907	10.7
1975	-	-	-	-	-
1976	-	-	-	-	-
1977	-	-	-	-	-
1978	-	-	-	-	-
1979	450	16	459	981	28.1
1980	1133	14	774	1463	80.9
1981	1530	24	1262	1212	63.3
1982	349	24	413	845	14.5
1983	371	23	485	765	16.1
1984	1523	46	1272	1197	33.1
1985	2546	107	2887	882	23.8
1986	1942	88	2270	856	22.1
1987	1141	57	n/a	-	20.0
1988	447	30	n/a	-	14.9
1989	155	14	n/a	-	11.1
1990	88	11	n/a	-	8.0
1991	457	24	n/a	-	19.0
1992	1296	72	n/a	-	18.0
1993	2122	71	n/a	-	29.9
1994	2294	80	2769	828	28.7
1995	1497	43	2113	708	34.8
1996	1204	46	1385	869	26.2
1997	1205	45	1313	918	26.8

n/a = not available

[1] Sources of landing and effort statistics:
1969-81: CAFSAC Res. Doc. 82/02
1982-83: CAFSAC Res. Doc. 86/77
1984-90: Can. MS Rept. 2154
1990-92: Science Branch, Gulf Region
1993: Statistics Branch, Newfoundland Region
1994-97: Science Branch, Newfoundland Region

Table 3. Summary of parameters used in estimating fishable biomass of Iceland scallops in the Strait of Belle Isle (1995).

	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Total
No. sets by strata	4	20	4	50	7	17	102
Total catch (kg)	10.2	124.1	9.8	375.9	14.0	1.1	535.1
Mean catch (kg)/tow	2.6	6.2	2.5	7.5	2.0	0.1	5.2
No. of track points (scallop bottom)	189	1272	302	4023	229	354	6369
% scallop bottom	36.6	47.9	49.8	57.6	21.0	14.1	44.3
No. of track points (hard & soft bottom)	327	1386	305	2958	822	2153	7951
% hard and soft bottom	63.4	52.1	50.3	42.3	75.5	85.5	55.3
Total track points	516	2658	607	6987	1089	2519	14376
Area (n mi^2)	4.5	37.9	4.6	162.2	39.2	598.7	847.1
% of total area surveyed	0.5	4.5	0.5	19.2	4.6	70.7	100.0

Table 4. Summary of parameters used in estimating fishable biomass of Iceland scallops in the Strait of Belle Isle (1997).

	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7	Total
No. of sets	1	26	1	50	4	63	3	148
Total catch (kg)	0.0	97.3	0.4	241.2	6.5	29.3	14.4	389.0
Mean catch (kg)/tow	0.0	3.7	0.4	4.8	1.6	0.5	4.8	2.6
No. track points (scallop & scallop bottom)	35	2223	90	2688	56	2208	215	7515
% scallop & scallop bottom	21.3	58.5	67.7	68.3	14.2	30.4	51.2	46.7
No. track points (hard & soft bottom)	129	1580	43	1249	338	5046	205	8590
% hard and soft bottom	78.7	41.6	32.3	31.7	85.8	69.6	48.8	53.3
Total track points	164	3803	133	3937	394	7254	420	16105
Area (n mi^2)	4.5	72.4	4.6	190.6	17.7	320.2	1.0	610.9
% of total area surveyed	0.7	11.9	0.8	31.2	2.9	52.4	0.2	100.0

Table 5. Biomass estimates (4R) for 1997 using scallop 'beds' only.

Area	Size ($n\ mi^2$)	No. of sets	$\bar{x}$/tow (kg)	MDB (t, round)
2	72.4	26	3.74	223-600 ($\bar{x}$ = 412)
4	190.6	50	4.82	1,103-1,692 ($\bar{x}$ = 1,398)
5	17.7	4	1.62	0-107 ($\bar{x}$ = 44)
7	1.0	3	4.78	2-12 ($\bar{x}$ = 7)
Combined	281.7	83		1,514-2,207 ($\bar{x}$ = 1,860)

Table 6. Mean and modal shell heights (mm) of Iceland scallops in the northern Gulf of St. Lawrence, 1995 and 1997.

Year	N	Mean shell height (mm) (±S.D.)	Modal shell height (mm)	Range (mm)	
				Max.	Min.
1995	3,405	86.8 (±8.6)	90	111	24
1997	3,257	87.3 (±8.9)	90	114	45

Table 7. Biological meat yields, average meat weight and meat counts of Iceland scallops from the northern Gulf of St. Lawrence, 1995 and 1997. No corrections made for epibiont load.

Year	N	Whole wt. (kg)	Meat wt. (kg)	$\bar{x}$ meat wt. (g)	Count		Yield (%)
					No./lb	No./500 g	
1995	921	105.3	10.79	11.7	39	43	10.3
1997	555	68.7	8.77	15.8	29	32	12.8

Table 8. Iceland scallop effort and removals south of 51°25'N in the northern Gulf of St. Lawrence, 1994-97. Based on log entries only not on dockside monitoring.

Year	Total		Percent south of 51°25'N		Bed 4 only	
	Removals (t, round)	Effort (boat days)	Removals	Effort	Removals	Effort
1994	2,294	2,769	43%	42%	n/a	n/a
1995	1,497	2,113	46%	47%	8%	38%
1996	1,204	1,385	67%	61%	6%	31%
1997	1,205	1,313	83%	80%	2%	13%

Table 9. CPUE estimates (non-standardized) for the Iceland scallop fishery in the northern Gulf of St. Lawrence, 1994-97. Total removals for 1994-96 are based on combination of sales slip and log estimates. Total removals for 1997 are from the Dockside Monitoring Program.

Year	Month	Removals (t, round)	Fishing days	CPUE (lb/tow)
1994	May	1.6	3	47
	June	822.9	936	83
	July	1,004.5	1,192	78
	August	252.1	369	63
	September	211.9	266	65
	October	1.1	3	64
	TOTALS	2,294.2	2,769	76
1995	June	259.9	352	62
	July	506.7	697	63
	August	477.5	627	66
	September	234.5	391	57
	October	18.6	46	50
	TOTALS	1,497.1	2,113	63
	% change 1994-95	-35%	-24%	-17%
1996	June	374.8	460	64
	July	476.1	532	71
	August	331.9	363	81
	September	20.4	29	73
	October	0.8	1	74
	TOTALS	1,204.1	1,385	71
	% Change 1995-96	-20%	-34%	+13%
1997	June	351.8	383	70
	July	446.2	527	79
	August	278.4	397	75
	September	1.9	5	55
	Unaccounted by logbook	126.5	1	-
	TOTALS	1204.8	1313	75
	% Change 1996-97	0%	-5%	+6%

Table 10. Within-season non-standardized catch rates for 4R scallops, 1997.

Week	Dates	Removals (t, round)	Fishing days	CPUE (lbs/tow)
1	June 2-8	65.7	77	67
2	June 9-15	79.3	86	72
3	June 16-22	78.9	85	70
4	June 23-29	94.4	105	71
5	June 30-July 6	97.9	110	73
6	July 7-13	105.0	105	84
7	July 14-20	95.4	117	77
8	July 21-27	100.9	116	80
9	July 28-August 3	108.5	159	75
10	August 4-10	112.3	138	82
11	August 11-17	101.0	148	72
12	August 18-24	36.9	60	68
13	August 25-31	0.1	1	24
14	September 1-7	0.6	3	41
15	September 8-14	1.3	2	66
Unknown	(not accounted in logs)	126.5	1	-
Overall		1,204.8	1,313	75

Table 11. Non-standardized CPUE estimates (lbs/tow) by vessel size class (LOA) for the Iceland scallop fishery in the northern Gulf of St. Lawrence, 1997.

Week	Dates	<35'	35-44'	45-54'	55-64'	Combined
1	June 2-8	101.6	59.6	41.7	-	66.6
2	June 9-15	96.1	66.0	49.8	-	71.9
3	June 6-22	92.6	66.9	50.7	-	70.2
4	June 23-29	86.4	69.6	56.4	-	71.1
5	June 30-July 6	89.0	71.8	58.8	-	73.4
6	July 7-13	92.8	88.9	65.1	-	83.6
7	July 14-20	90.3	80.4	56.4	94.0	77.2
8	July 21-27	93.1	84.1	58.2	111.0	80.4
9	July 28-August 3	83.1	79.5	56.8	92.0	74.8
10	August 4-10	84.8	85.8	72.0	86.3	82.1
11	August 11-17	78.7	76.5	57.0	-	71.9
12	August 18-24	78.0	69.8	55.3	-	67.7
13	August 25-31	-	23.7	-	-	23.7
14	September 1-7	79.7	11.5	-	-	40.7
15	September 8-14	72.6	-	61.3	-	66.3
	1997 Overall	88.3	74.7	57.4	95.1	74.7
	1996 Overall	99.8	65.5	58.3	119.9	70.7
	1995 Overall	60	58	52	60	57
	No. vessels (1997)	17	18	9	1	45
	% of weight removed (1997)	33%	37%	18%	1%	89%*

* 126.5 t of landings unaccounted by logbook data

Table 12. Natural mortality estimates in the Iceland scallop from northeastern Gulf of St. Lawrence, 1995 and 1997. Clucker numbers are adjusted by a factor of 1.2 to allow for tow-induced disarticulation.

Year	Live	Cluckers	M
1995	3,548	411.5	0.18
1997	3,788	393.2	0.16

Table 13. Mean numbers and weights (kg) of four starfish species in the main commercial fishery areas for Iceland scallops in the Newfoundland area.

Area	# of sets	Leptasterias sp.		Crossaster sp.		Asterias sp.		Solaster sp.	
		mean #/tow (±S.D.)	mean wt./tow (±S.D.)	mean #/tow (±S.D.)	mean wt./tow (±S.D.)	mean #/tow (±S.D.)	mean wt./tow (±S.D.)	mean #/tow (±S.D.)	mean wt./tow (±S.D.)
4R	148	124.6 (±198.1)	11.7 (±18.9)	42.6 (±80.1)	3.5 (±7.9)	<0.1	<0.1	1.2 (±3.4)	0.2 (±0.7)
LCC	106	105.5 (±113.8)	23.3 (±25.2)	19.3 (±24.0)	2.4 (±2.9)	0.1 (±0.9)	<0.1	2.8 (±6.0)	0.8 (±2.0)
3Nf	59	4.3 (±9.4)	0.8 (±1.7)	15.4 (±20.4)	1.7 (±2.4)	0.1 (±0.5)	<0.1	2.7 (±5.6)	0.9 (±2.3)
3Ps Strat. 22	42	107.2 (±96.8)	15.8 (±14.1)	67.5 (±60.5)	9.4 (±8.7)	30.4 (±108.5)	1.7 (±7.6)	1.2 (±1.3)	0.5 (±0.5)

Table 14. Weight and size (arm radii) characteristics of populations of starfish in 4R (1997), compared with those from 3Ps (1996) and the Grand Banks of Newfoundland, NAFO Div. 3N (Lilly Canyan/Carson Canyon and 3Nf, 1997).

	Leptasterias sp.				Crossaster sp.				Asterias sp.				Solaster sp.			
	4R	LCC	St. 22	3Nf	4R	LCC	St. 22	3Nf	4R	LCC	St. 22	3Nf	4R	LCC	St. 22	3Nf
Weight sampled (kg)	380	1104	272	42	147	220	21	9	<1	<1	21	9	10	90	18	53
Nos. Sampled	4093	5114	1884	255	1838	1922	623	7	1	14	623	7	61	356	46	159
Mean Individual weight (g)	90	215	145	165	80	115	30	21	80	22	30	21	160	253	270	335
Mean arm radius (cm)	8	12	10	11	7	7.5	6	4	8	4	6	4	10	11	13	11
No. of tows completed in area (#s with starfish)	148 (132)	114 (100)	98 (41)	59 (22)	148 (134)	114 (85)	98 (22)	59 (4)	148 (1)	114 (5)	98 (22)	59 (4)	148 (28)	114 (55)	98 (25)	59 (24)

Table 15. Estimates of total area dredged by fishing in the northern Gulf of St. Lawrence, 1995-97. Computations assume 10 ft. swath of perturbation to sea bottom.

Year	Total no. of tows (% of total records reported)	Linear distance (n mi)		Area covered (n mi^2)	
		1/2 mi tow	1 mi tow	1/2 mi tow	1 mi tow
1995	52,007 (98%)	26,004	52,007	42.8	85.5
1996	35,634 (94%)	17,817	35,634	29.3	58.6
1997	31,475 (94%)	15,738	31,475	25.9	51.8

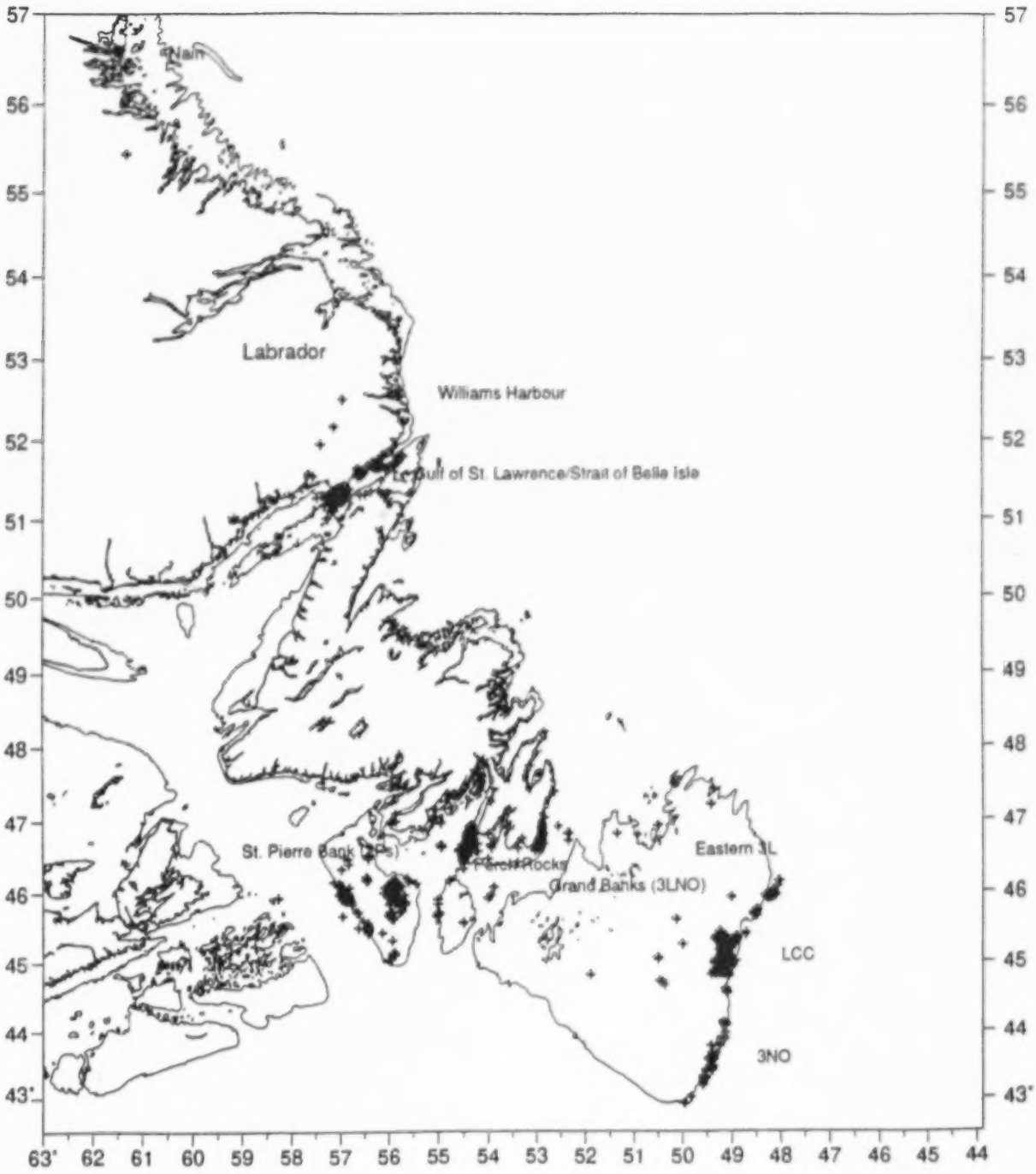

Fig. 1. Iceland scallop aggregations fished in Newfoundland, 1997.

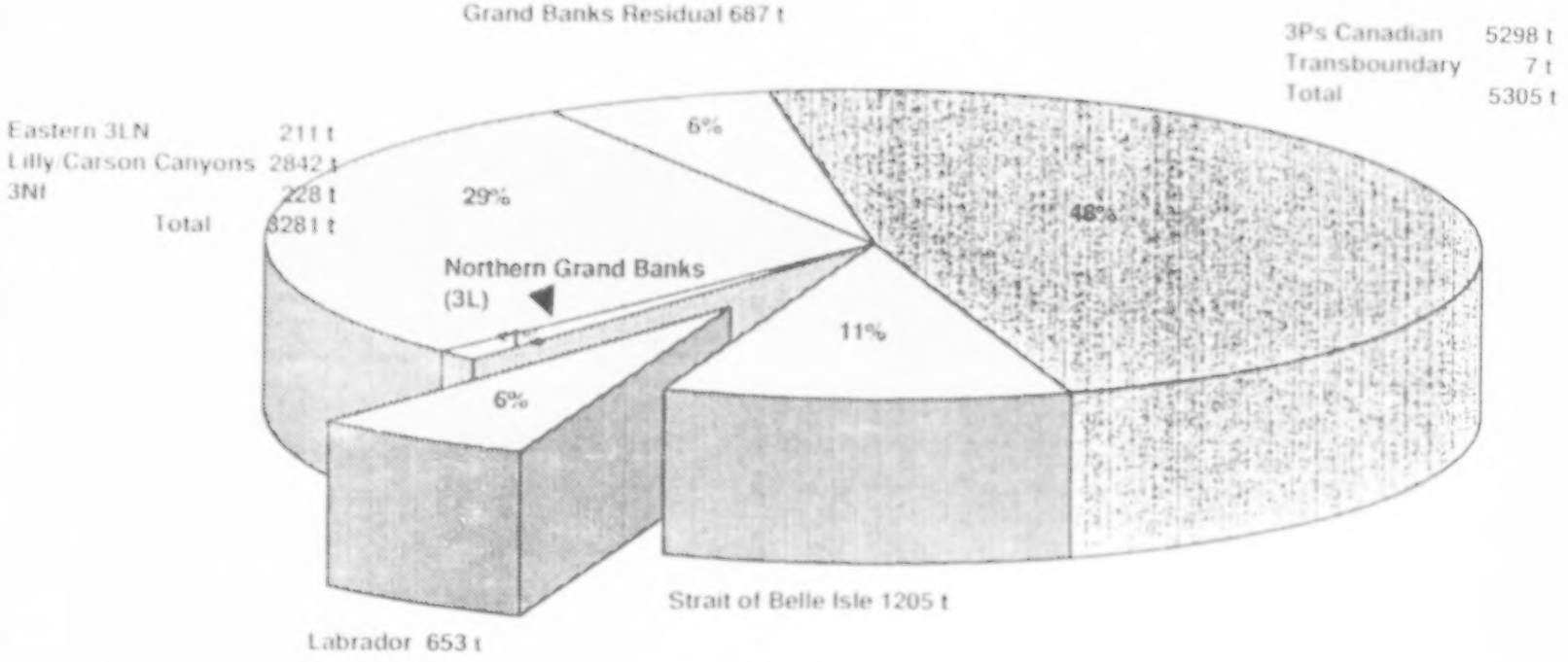

Fig. 2. Removals (% and t,round) of the Iceland scallop from Newfoundland, 1997.

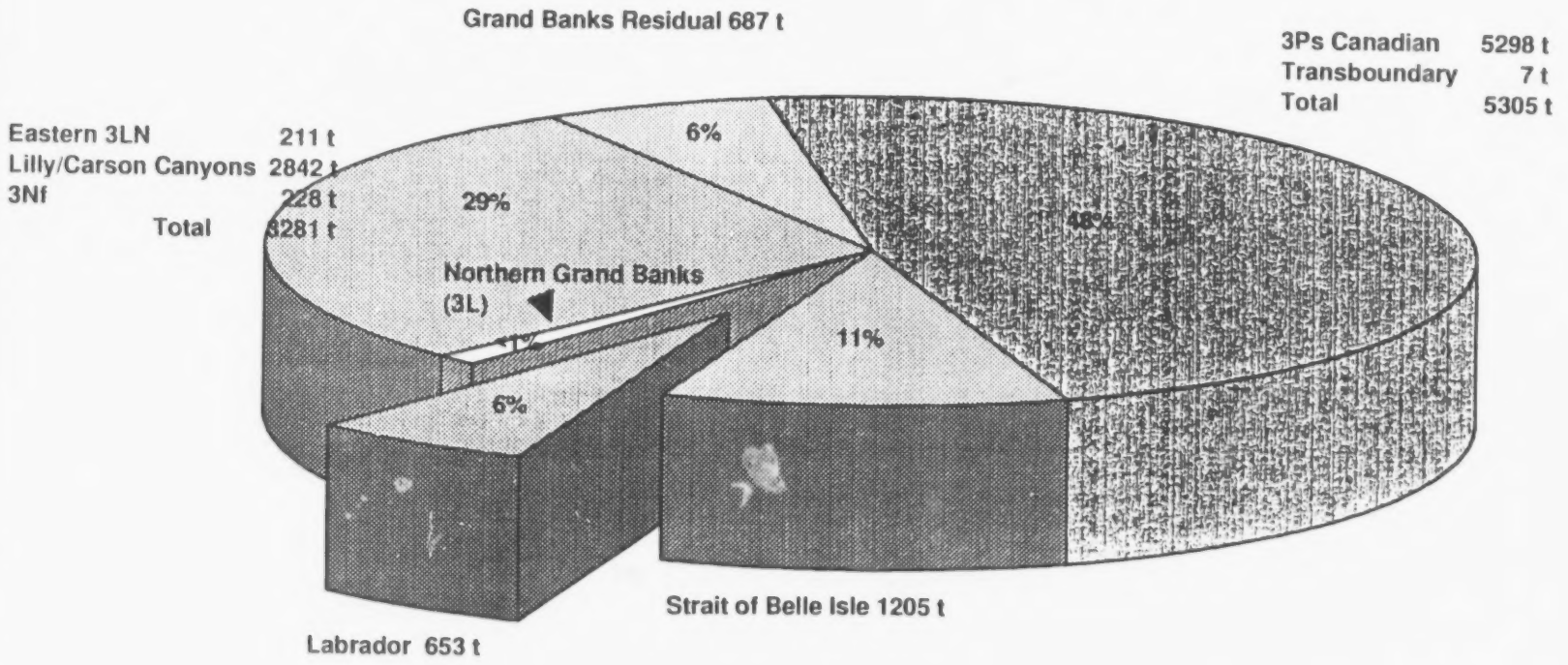

Fig. 2. Removals (% and t,round) of the Iceland scallop from Newfoundland, 1997.

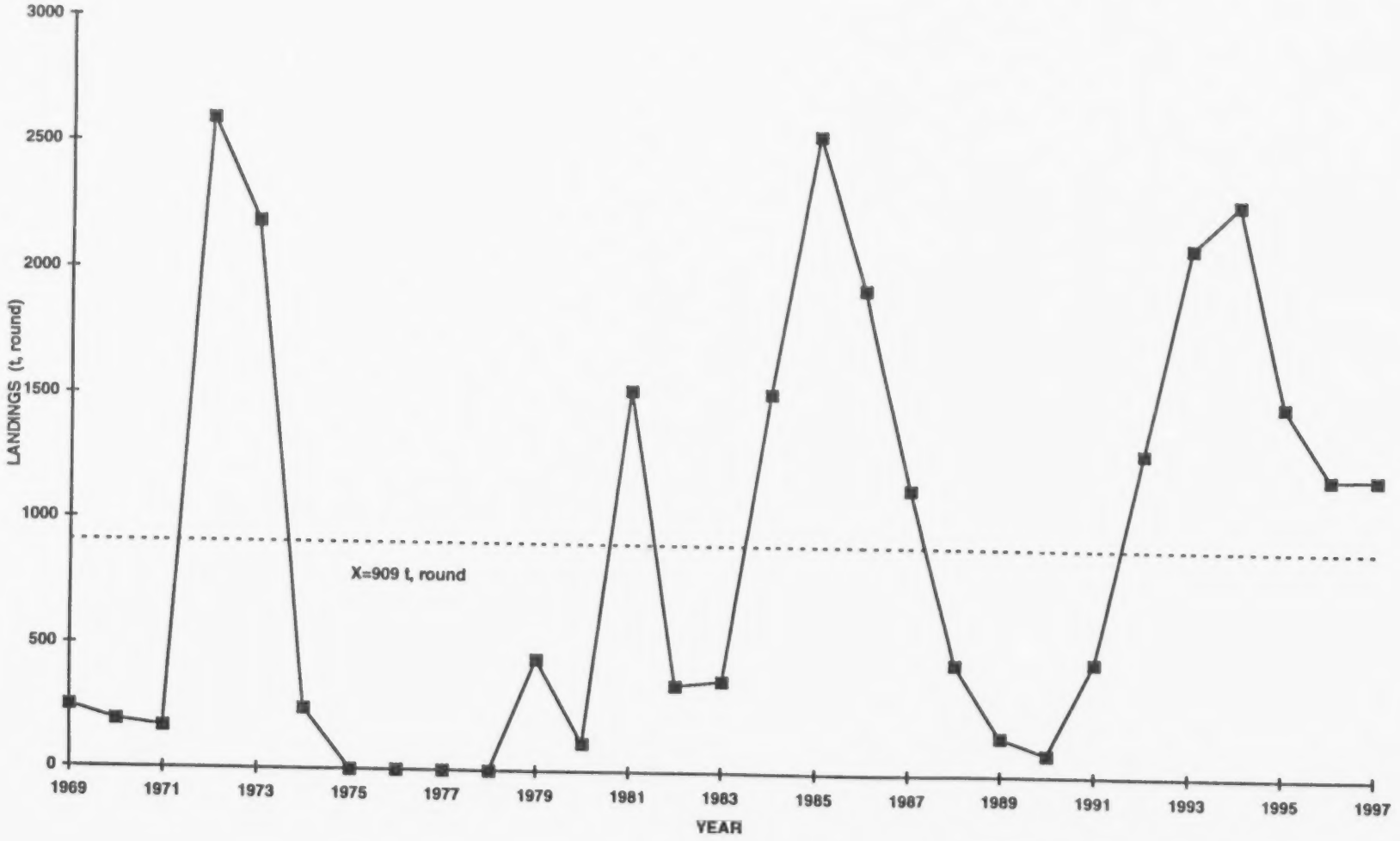

Fig.3. Iceland scallops in 4R: Catches (1969-97)and TACs(1994-97)

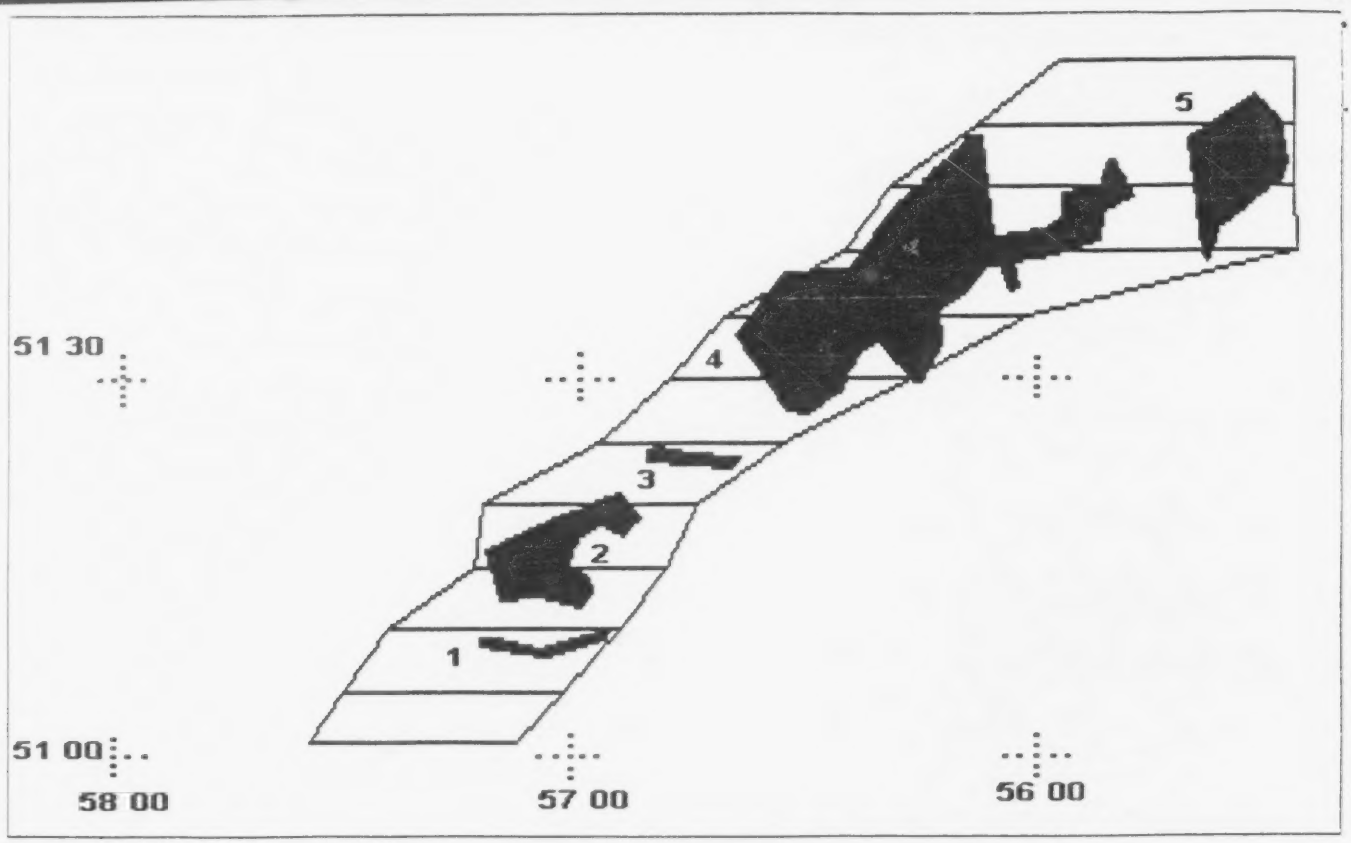

Fig. 4. Distribution of scallop beds in 4R as configured in 1995.

	1	2	3	4	5	6	TOTAL
NO. SETS BY STRATA	4	20	4	50	7	17	102
TOTAL CATCH (kg) IN EACH STRATUM	10.2	124.1	9.8	375.9	14.0	1.1	535.1
MEAN CATCH (kg)/TOW	2.6	6.2	2.5	7.5	2.0	0.1	5.2
NO. OF TRACK POINTS (SCALLOP BOTTOM)	189	1272	302	4023	229	354	6369
% SCALLOP BOTTOM	36.6	47.9	49.8	57.6	21.0	14.1	44.3
NO. OF TRACK POINTS (HARD& SOFT BOTTOM)	327	1386	305	2958	822	2153	7951
% HARD & SOFT BOTTOM	63.4	52.1	50.3	42.3	75.5	85.5	55.3
TOTAL TRACK POINTS	516	2658	607	6987	1089	2519	14376
NAUTICAL MI^2	4.5	37.9	4.6	162.2	39.2	598.7	847.1
% OF TOTAL AREA SURVEYED	0.5	4.5	0.5	19.2	4.6	70.7	100.0

Table 3 . Summary of parameters used in estimating fishable biomass of Iceland scallops in the Strait of Belle Isle (1995).

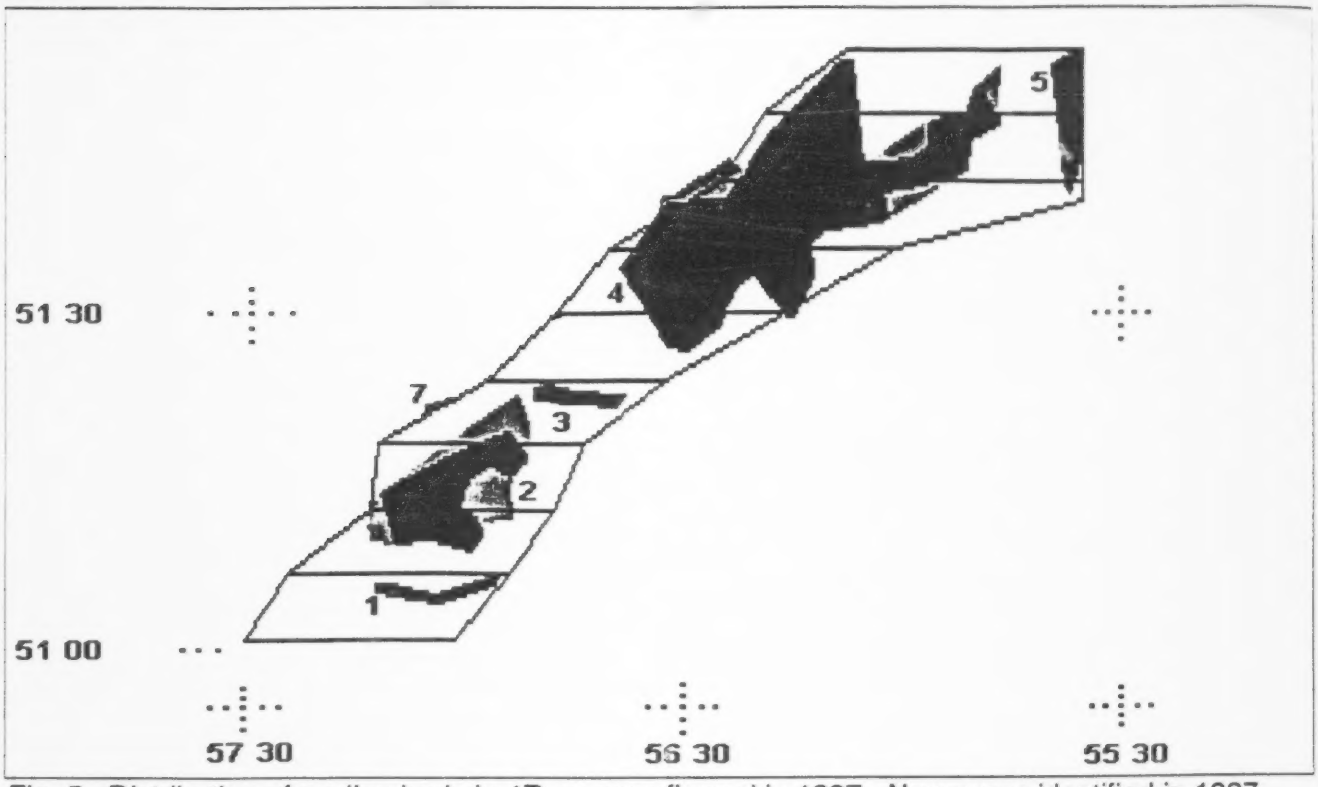

Fig. 5. Distribution of scallop beds in 4R as reconfigured in 1997. New areas identified in 1997 are shaded in grey.

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6	AREA 7	TOTAL
# SETS	1	26	1	50	4	63	3	148
TOTAL CATCH (kg)	0.0	97.3	0.4	241.2	6.5	29.3	14.4	389.0
MEAN CATCH (kg)	0.0	3.7	0.4	4.8	1.6	0.5	4.8	2.6
# TRACK POINTS (SCALLOP & SCALLOP BOTTOM)	35	2223	90	2688	56	2208	215	7515
% SCALLOP & SCALLOP BOTTOM	21.3	58.5	67.7	68.3	14.2	30.4	51.2	46.7
# TRACK POINTS (HARD & SOFT BOTTOM)	129	1580	43	1249	338	5046	205	8590
% HARD & SOFT BOTTOM	78.7	41.6	32.3	31.7	85.8	69.6	48.8	53.3
TOTAL TRACK POINTS	164	3803	133	3937	394	7254	420	16105
AREA (Square nautical miles)	4.5	72.4	4.6	190.6	17.7	320.2	1.0	610.9
% OF TOTAL AREA SURVEYED	0.7	11.9	0.8	31.2	2.9	52.4	0.2	100.0

ROXANN data missing for 15 sets

Table 4. Summary of parameters used in estimating fishable biomass of iceland scallops in the Strait of Belle Isle (1997)

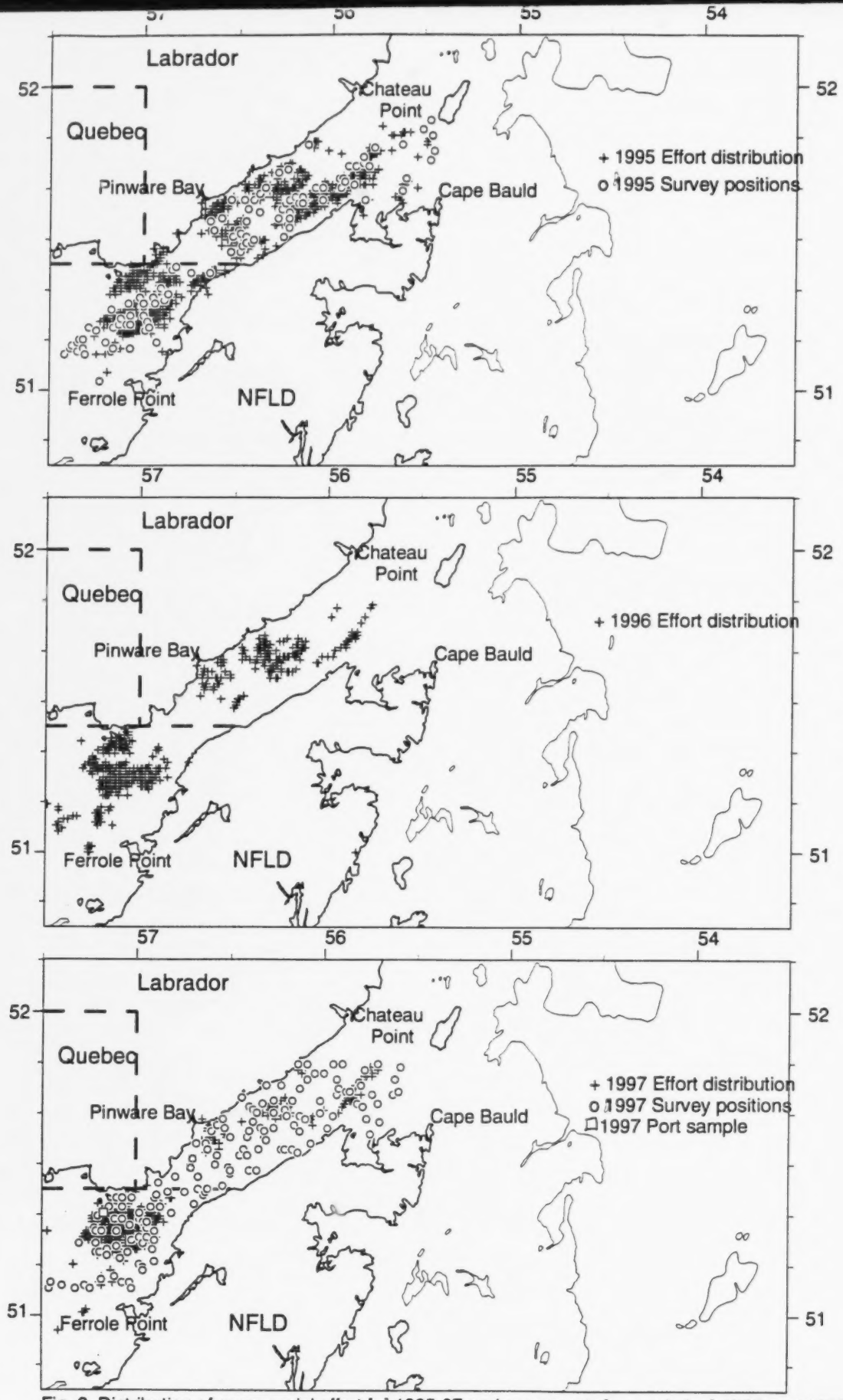

Fig. 6. Distribution of commercial effort [+] 1995-97 and survey sets [open circles],1995 and 1997 only in the Strait of Belle Isle. The small box along lat. 51 20 identifies origin of the single commercial sample in 1997.

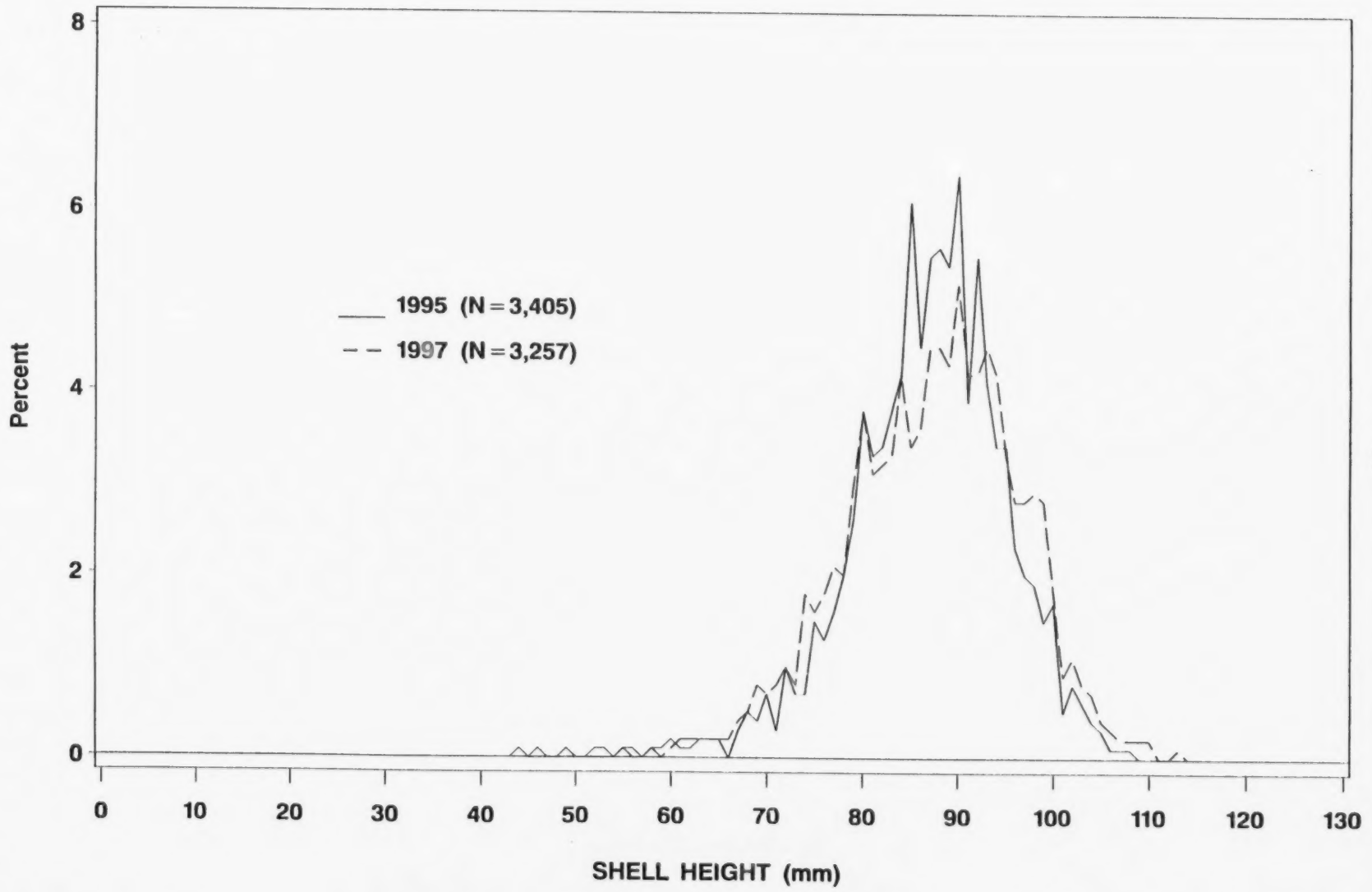

Fig. 7. Research size frequencies (shell height, mm) of Iceland scallops from 4R, 1995 and 1997.

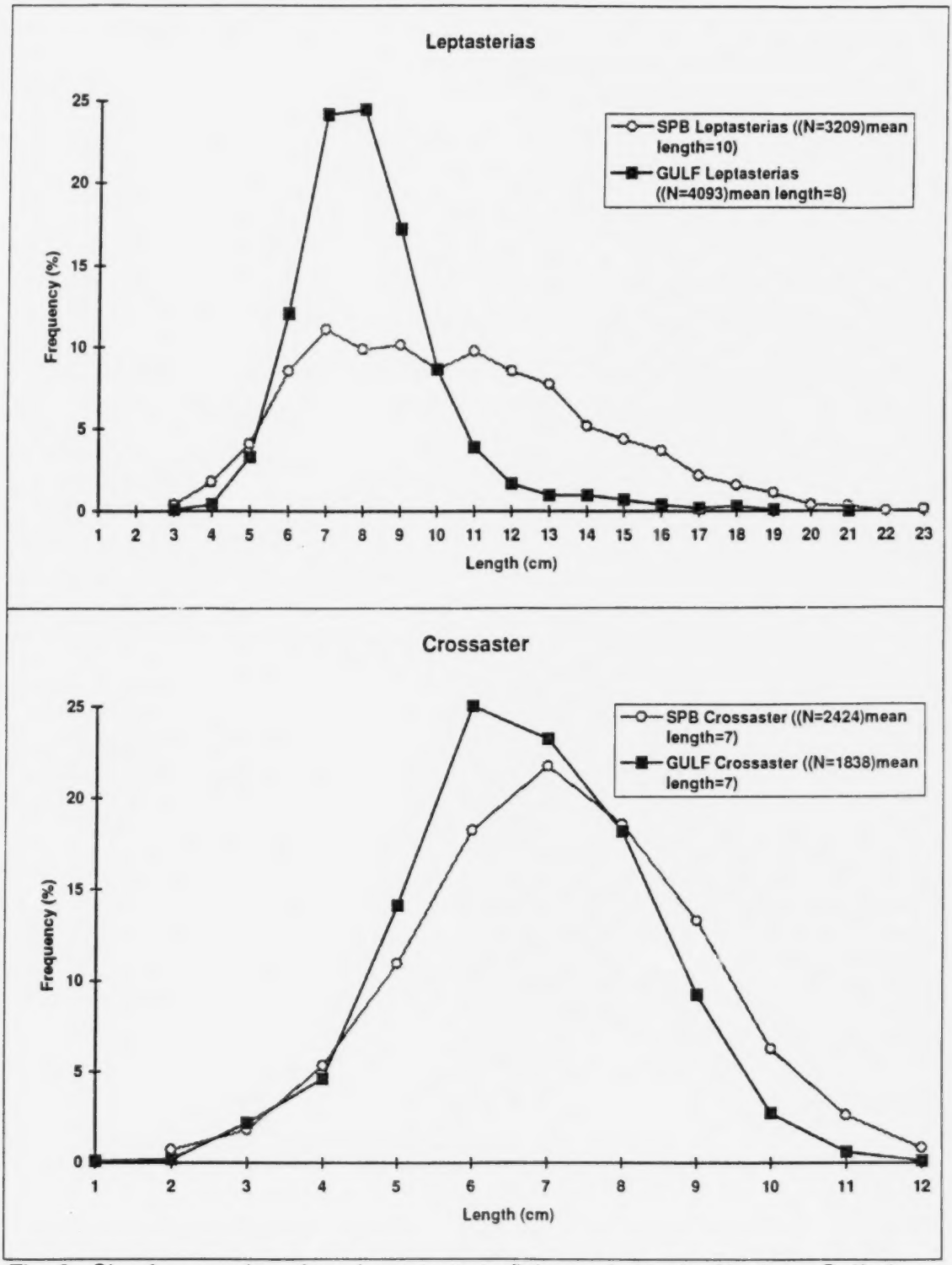

Fig. 8. Size frequencies of two important starfish species in the Northern Gulf of St.Lawrence/Strait of Belle Isle (1997) and St. Pierre Bank (1996). Observations were made on board Canadian research vessels.

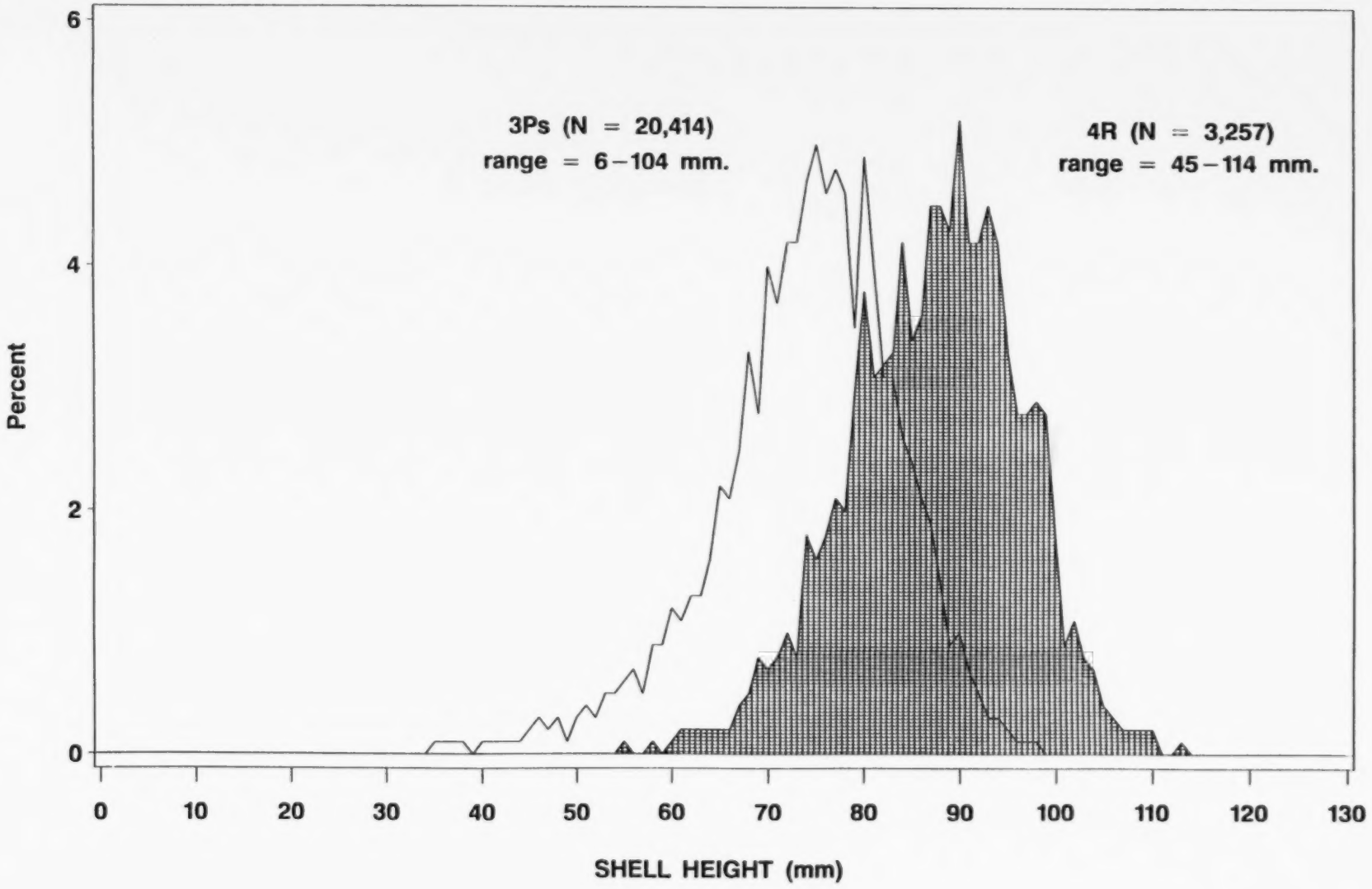

Fig. 9. Size frequency (shell height, mm) distribution in the Iceland scallop from 4R (Gulf of St. Lawrence) compared with 3Ps (St. Pierre Bank).